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Forest Health Protection

Pacific Southwest Region

Date: July 10, 2001
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To: District Ranger, Truckee Ranger District, Tahoe National Forest

Subject: Crystal Fire Marking Guidelines For Fire Injured Trees
Administrative Study Monitoring Report (NE_SPR_01-01)

Background Information

This study was implemented in June 1995 to evaluate the survivability of selected conifers that suffered different degrees of fire injury during the 1994 Crystal Fire. A total of 115 trees were selected, 55 ponderosa pine (*Pinus ponderosa*) and 60 Jeffrey pine (*Pinus jeffreyi*), representing a range of post-wildfire related injuries.

The Crystal Fire began on August 4, 1994 and eventually burned approximately 7,300 acres on the Truckee Ranger District, Tahoe National Forest and the Carson Ranger District, Toiyabe National Forest (Figure 1). The area is located in the 22" to 26" isohyetal precipitation zone at an elevation range between 5,000 to 7,500 feet. This area had experienced an extended period of below normal precipitation for the seven years leading up to the fire. High levels of white fir mortality, associated with the protracted drought period and fir engraver beetle attacks, were detected in this area throughout the early 1990's. As a result of this mortality the amount of standing dead fuel was extremely high. The burned area consisted of four forest types, red fir/red fir mixed conifer, white fir/Jeffrey pine/ponderosa pine, Jeffrey pine/ponderosa pine/bitterbrush and Jeffrey pine/ponderosa pine/mountain mahogany.

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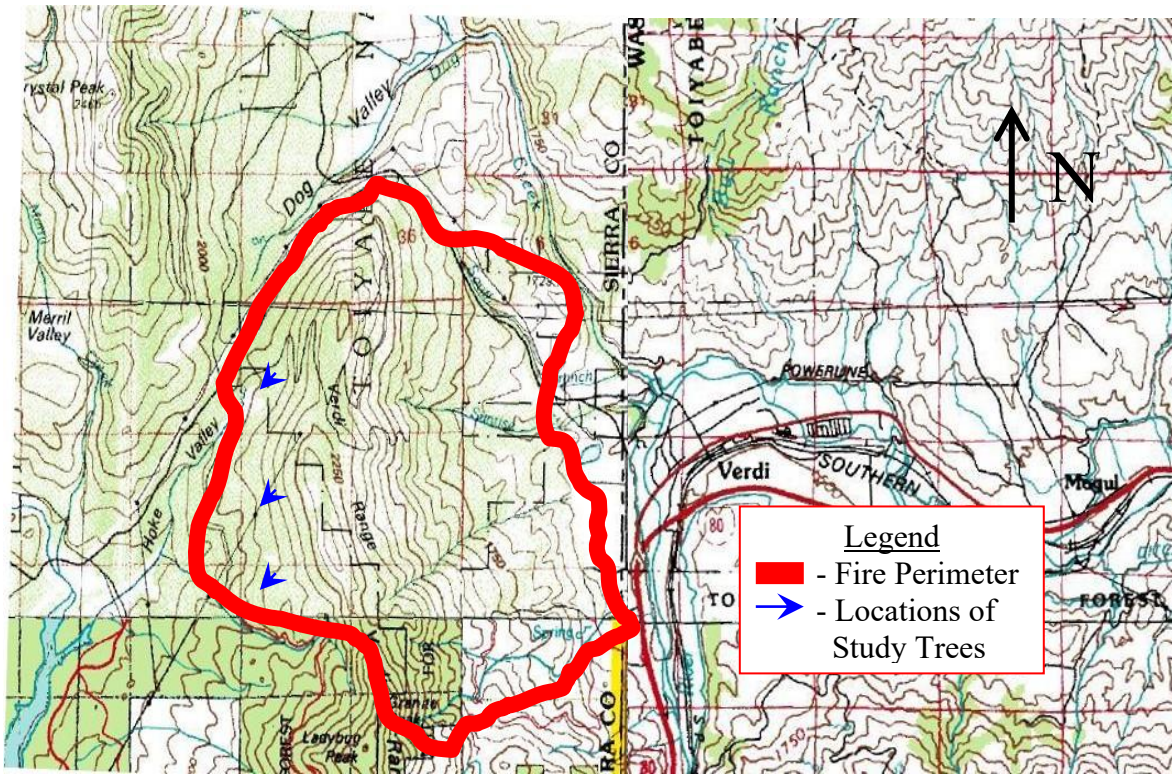
Fire intensity ranged from areas of complete vegetative consumption to areas of light under burning (Crystal Fire EA 1995). Rehabilitation efforts, focusing on preventing erosion and marking of salvage timber, began immediately following the fire.

Figure 1. Perimeter of Crystal Fire and Location of Study Trees



Salvage marking continued in Spring/Summer 1995 and included a re-evaluation of the previously marked stands to assess any change in tree condition over the winter. Tree survivability was determined by using guidelines adapted from Wagener (1961) (Appendix A).

Accurately evaluating fire damage and predicting survivability of trees is critical when planning rehabilitation and salvage operations. Tree survival from a given level of damage varies widely between species and sites. Localized fire effects relationships are essential tools for determining survivability yet few have been established. Documentation of fire effects on tree survival is necessary for providing the information required to establish these localized fire effects relationships (Ryan 1983). The Crystal Fire presented Forest Health Protection (FHP) personnel with an opportunity to monitor and evaluate the survivorship of individual Jeffrey pine and ponderosa pine, with various degrees of fire injury, on the eastside of the Sierra Nevada. It also allowed us to test the accuracy of Wagener's guidelines, the most widely used for estimating survival of fire-injured trees in California, when locally applied to an eastside forest type experiencing drought conditions. Information obtained from this study can be used to support, enhance, or modify salvage marking guidelines and to assist in determining post fire bark beetle

response for these conifer species under similar conditions.

Monitoring

The 115 ponderosa and Jeffrey pine trees were originally evaluated, documented, and photographed during June 1995. All selected trees had some degree of fire-related injury. Red fir and white fir, though present in burned area, were not considered in this study. Data collected included diameter breast height (DBH), height, and remaining live crown, recorded as a percentage of the original crown. It was determined at time of tree selection that remaining green crown was equal to remaining live crown. Therefore, percent crown scorch referred to in this report equals 100 percent minus percent live crown. Cambium samples were collected in Summer 2000 from all live trees to quantify the amount of damage. Four plugs were taken in the cardinal directions using a gas-powered drill and 1" hole-saw bit. A corresponding rating (0 - 4), based on number of dead samples, was then assigned to each tree. These ratings were assumed to correspond to percent cambium kill (e.g. 0 = 0 %, 1 = 25 %, 2 = 50 %, etc.). This method of cambium sampling is relatively quick and provides some indication of cambium kill while minimizing damage to the tree. In addition, all signs and symptoms of bark beetle attacks, disease infections and mechanical injury were documented. All trees were monitored annually for five years to document any changes from their initial conditions.

Results

The ranges of characteristics and conditions of the trees, at the time of selection, are summarized in Table 1. All reported results combine data taken for both Jeffrey and ponderosa pines as no difference in survival rate was found (JP = 80 %, PP = 84 %). Six trees had bark beetle activity (*Dendroctonus spp.*), other than red turpentine beetle (*Dendroctonus valens*), at time of selection. As of August 10, 2000, 94 trees out of the original 115 remain alive resulting in an overall survival rate of 81.7 %. Based on Wagener's guidelines (greater than 50 % live crown and/or <25 % cambium injury) the number of trees predicted to survive was 48/115 or 41.7 %. The mortality by year and associated bark beetle activity are displayed in Figure 1.

Table 1. Characteristics and Conditions of Selected Trees

	Height Range (feet)	DBH Range (inches)	% Live Crown Range	Cambium Kill Rating
Jeffrey pine (60)	43 – 108	15.2 – 31.3	18 - 100	0 – 4
Ponderosa pine (55)	32 – 83	13.7 – 33.3	14 - 100	0 – 4

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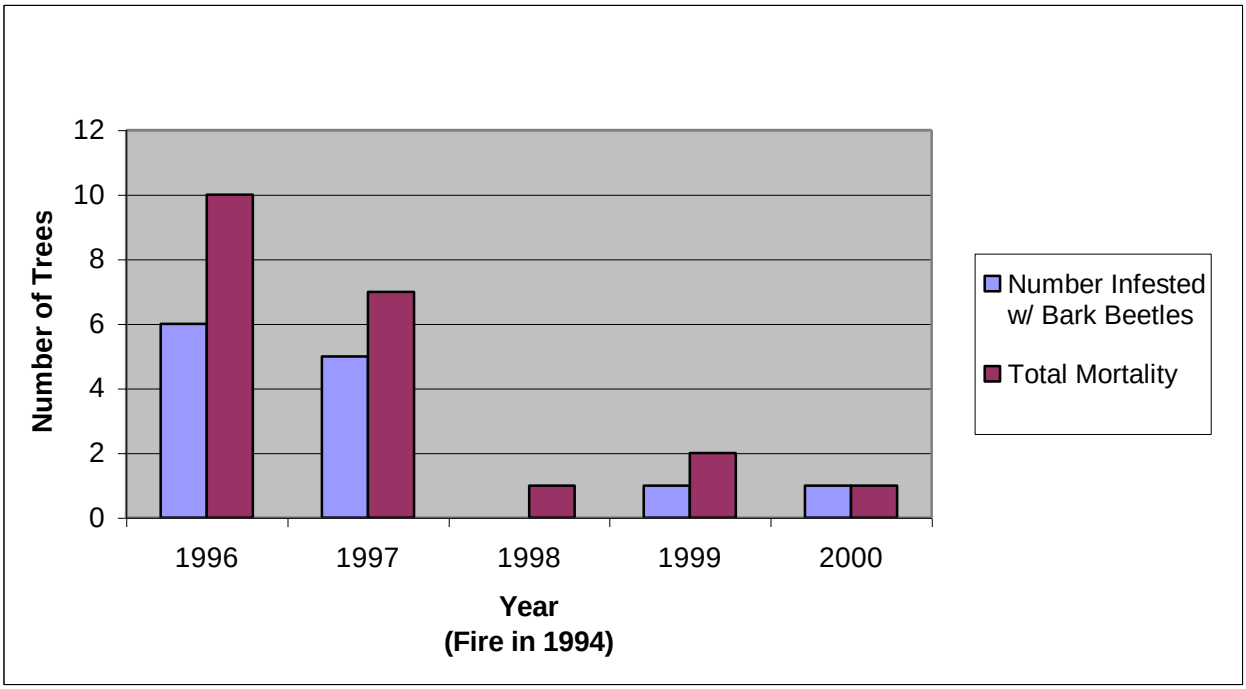
Figure 1. Mortality by Year and Associated Primary Bark Beetle Activity



The data collected allowed for a comparison of variables such as percent live crown and tree DBH between live and dead trees and between trees with cambium kill ratings of 0 – 1, defined as no damage to moderate damage (< 25%), and 2 – 4, defined as severe damage (> 25%) (live trees only). These variables were analyzed using a standard t-test of means (Sokal and Rohlf 1987). Only sampled trees with at least 5 % crown scorch were used to calculate the means for live trees. Mean DBH and mean percent live crown were both significantly different between live and dead trees (Table 2). No significant differences were found between live trees with different cambium kill ratings (Table 3). Various statistical analyses, including analysis of variance (ANOVA) and coefficient correlations (Sokal and Rohlf 1987), were conducted to determine relationships among cambium kill ratings (0 – 4), % live crown, and DBH. Results indicated that these variables were not significantly related.

Table 2. Mean Percent Live Crown and DBH Differences Between Live and Dead Trees

	Mean % Live Crown	Mean DBH
Live Trees n = 79	53.3 $\pm$ 18.1	19.0 $\pm$ 5.4
Dead Trees n = 21	38.0 $\pm$ 15.8	17.5 $\pm$ 2.5
p - value	<0.0004	<0.04

Table 3. Mean Percent Live Crown and DBH Differences Between Live Trees With Cambium Kill Ratings of 0 – 1 (none to moderate, < 25 %) and 2 – 4 (Severe, > 25%)

	Mean % Live Crown	Mean DBH
Rating of 0 – 1 n = 53	54.2 $\pm$ 17.5	18.9 $\pm$ 5.8
Rating of 2 – 4 n = 25	49.7 $\pm$ 17.3	19.0 $\pm$ 5.2
p - value	Not Significant at $\alpha = 0.05$	Not Significant at $\alpha = 0.05$

Survival based on various levels of crown scorch is presented in Table 4.

Table 4. Tree Survival For Different Crown Scorch Percentiles

Percent Crown Scorch	Total Number Of Trees	Number Alive as of Fall 2000	Percent Survival
0 – 10	17	17	100
11 – 20	3	3	100
21 – 30	10	9	90
31 – 40	17	14	82
41 – 50	19	19	100
51 – 60	21	17	81
61 – 70	10	5	50
71 – 80	15	8	53
81 – 90	3	2	67
91 – 100	0	0	N/A

Discussion

Wagener's guidelines, which use cambium damage and/or remaining live crown, when applied to trees selected for this study predicted a survivability rate of 41.7 %. The result after five years is a survivability rate of 81.7 %. It appears Wagener's guidelines were far too conservative in predicting survivability given those 46/115 trees, or 40.0 %, that would have been salvage cut are still alive. When looking at crown scorch and cambium damage independently Wagener's guidelines predicted survivability rates of 57.4 % and 58.3 % respectively. Again, these predictions are much lower than the actual rate of 81.7 %. The low predicted survival rates, other than for crown scorch alone, might be partially attributed to our assessment of cambium damage. Overestimates of percent cambium kill may have occurred, particularly as DBH increased. The higher rate of observed survival may be partially attributed to the extended

period of above normal precipitation and a return to endemic levels of bark beetle related mortality that we have experienced in the study area beginning in 1995.

No significant relationship between percent live crown (or percent crown scorch) and amount of cambium damage could be established in the Crystal Fire study. Furthermore, no significant relationship could be established between DBH and amount of cambium damage. This lack of correlation for these variables reveals why it is not possible to visually assess cambium damage without destructive sampling.

When trying to predict survivability of live trees following wildfire or prescribed burns it is important to remember that not all damage is identifiable with a visual inspection. Cambium damage is not equivalent to bark scorch (Weatherspoon 1988) and using bark scorch to assess cambium damage has not proved accurate in any situation (FHP evaluation reports). Thick duff layers surrounding boles can burn hot for extended periods causing extensive cambium damage without producing bark-scorching flames (Ryan and Frandsen 1991). In all cases, destructive sampling must be done in order to accurately assess cambium damage if this criterion is being used in marking guidelines. Destructive sampling, as practiced in this study, takes much more time than a visual inspection and therefore is typically impractical for extensive use by marking crews. Root damage is even more difficult to discern and definitely not practical for tree evaluation.

Percent crown scorch is the best predictor of tree mortality that is easily applied in the field. Studies of tree survival following burns in plantations have shown that percent crown scorch can be used to predict tree survival at a high rate of accuracy for trees with up to 60 % crown scorch (Herman 1954) and in some cases up to 80 % (Lynch 1959). Preliminary data from another FHP study on the 1999-2000 Divide Underburn, Volcano Plantation, Foresthill Ranger District, Tahoe NF, shows similar results. Data collected one year post-burn on mostly 6” to 16” DBH ponderosa pine shows an 89 % survival rate for trees with crown scorch up to 60 %, dropping to a 10 % survival rate for trees with crown scorch > 60 %. Data from the Crystal Fire, five years post-burn, shows a survival rate of 91 % for trees with crown scorch up to 60 %. The survival rate then drops to 55% for trees with crown scorch > 60 %.

The Crystal Fire presented an opportunity to monitor survivability of Ponderosa and Jeffrey pines subjected to different degrees of fire injury. It also allowed an assessment of Wagener’s marking guidelines for tree survival when trees had been injured following several years of below normal precipitation. However since the initiation of this study we have experienced above normal precipitation throughout northern California. The affect of higher than normal precipitation on this study is unknown and it is not possible to determine whether results obtained during a drier weather period would have been significantly different.

Accurately predicting survivability of fire-injured trees is essential when planning rehabilitation and salvage activities in burned areas particularly if the intent is to leave trees that are likely to survive. Currently Wagener’s “Guidelines for estimating survivability of fire-damaged trees in California” is one of only a few documents that are available to land managers. The Crystal Fire study has added to this limited amount of information with site-specific data. Based on this data and data obtained from other FHP studies we have determined that Wagener’s guidelines for

percent live crown should be adjusted from 50 % down to 35 % (Appendix B). It is also recommended that if the effort needed to sample cambium is impractical for salvage marking purposes than only percent crown scorch or percent live crown should be used to predict survivability of fire damaged ponderosa and Jeffrey pine in eastside forest types.

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Appendix A. Summary of Wagener's Guidelines for Ponderosa and Jeffrey Pine

Table A. General Specifications

Influencing Factors	Cambium Injury	% Live Crown	% Green Foliage
Fire period – late season Site quality – above average Growth vigor of tree before fire - good	None or light	≥ 50	≥ 10

Table B. Modifications (other general specifications unchanged)

Modified Influencing Factors	Cambium Injury	% Live Crown	% Green Foliage
In cambium injury – moderate	Moderate (≤25%)	≥ 50	≥ 20
In site – below average	None or light	≥ 50	≥ 15
In fire period – midseason	None or light	≥ 50	≥ 15 to 25
In growth vigor – crown small, vigor moderate	None or light	≥ 60	≥ 15

Appendix B. Recommended Modification of Wagener's Guidelines for Ponderosa and Jeffrey Pine

Table A. General Specifications

Influencing Factors	Cambium Injury	% Live Crown	% Green Foliage
Fire period – late season Site quality – above average Growth vigor of tree before fire - good	None or light	≥ 35	≥ 10

Table B. Modifications (other general specifications unchanged)

Modified Influencing Factors	Cambium Injury	% Live Crown	% Green Foliage
In cambium injury – moderate	Moderate (≤25%)	≥ 35	≥ 20
In site – below average	None or light	≥ 35	≥ 15
In fire period – midseason	None or light	≥ 35	≥ 15 to 25
In growth vigor – crown small, vigor moderate	None or light	≥ 35	≥ 15